

INVESTIGATION OF  
MIXING LENGTH PARAMETERIZATIONS  
IN A PROGNOSTIC MESOSCALE  
METEOROLOGICAL MODEL

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# What we have done:

Investigated sensitivity of mesoscale meteorological model to turbulence parameterizations of the tke- $\ell$ (k- $\varepsilon$ ) type.

## Why?

Lots of variation in the length scale parameterizations currently being used.

Here's what the authors of one of the more common diagnostic  $\ell$  parameterizations said:

*"There have been a number of equations to provide  $\ell$  ... all of which are on considerably shak[y] ground ..." Mellor and Yamada (1974)*

$$K_m = \alpha K_h = F_s \cdot \ell E^{1/2}$$

$$\varepsilon = \beta \cdot \frac{E^{3/2}}{\ell}$$

### **Case 1. Neutral stability length scale**

(e.g., Blackadar, 1962; Mellor and Yamada, 1974)

$$\ell = \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

### **Case 2. Stability-dependent length scale**

(e.g., Arritt, 1987)

$$\ell = \sqrt{\tilde{S}_M} \cdot \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

### **Case 3. Prognostic length scale**

(e.g., Mellor and Herring, 1973; Mellor and Yamada, 1982; Yamada, 1983)

$$\frac{\partial E \ell}{\partial t} = \dots$$

### **Case 4. Stability-dependent dual-choice length scale**

(André et. al., 1978; Duynkerke & Driedonks, 1987)

$$\ell_1 = \left( \frac{\phi_m}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$\ell = \min(\ell_1, \ell_2)$$

$$\ell_2 = 0.36 \cdot E^{\frac{1}{2}} \left( \frac{g}{\bar{\Theta}} \frac{\partial \bar{\Theta}}{\partial z} \right)^{-\frac{1}{2}} \text{ for } \frac{\partial \bar{\Theta}}{\partial z} \geq 0$$

### **Case 5. Prognostic dissipation and diagnostic eddy diffusivity length scales**

$$\frac{\partial E \ell_e}{\partial t} = \dots$$

$$\ell_{K_m} = \sqrt{\tilde{S}_M} \cdot \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$K_m = \alpha K_h = F_s \cdot \ell E^{1/2}$$

$$\varepsilon = \beta \cdot \frac{E^{3/2}}{\ell}$$

### Cases 1, 2, 3, 5

$$\ell = \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$\ell = \sqrt{\tilde{S}_M} \cdot \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$\frac{\partial E \ell}{\partial t} = \dots$$

$$\frac{\partial E \ell}{\partial t} = \dots \text{ and } \ell_{K_m} = \sqrt{\tilde{S}_M} \cdot \left( \frac{1}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$F_s = \sqrt{2} \tilde{S}_M$$

$$\alpha = \tilde{S}_M / \tilde{S}_H$$

$$\beta = \sqrt{2}^{3/2} / B_1 = 0.17$$

### Case 4

$$\ell = \min(\ell_1, \ell_2)$$

$$\ell_1 = \left( \frac{\phi_m}{kz} + \frac{1}{\ell_o} \right)^{-1}$$

$$\ell_2 = c E^{1/2} \left( \frac{g}{\Theta} \frac{\partial \Theta}{\partial z} \right)^{-1/2} \text{ for } \frac{\partial \Theta}{\partial z} \geq 0$$

$$F_s = c_m^{1/4} = 0.55$$

$$\alpha = 1$$

$$\beta = c_m^{3/4} = 0.16$$

### $\ell_o$ specification

$$\ell_o = c \cdot \int_0^{\infty} z E^{1/2} dz / \left( \int_0^{\infty} E^{1/2} dz \right), \quad 0.1 \leq c \leq 0.3$$

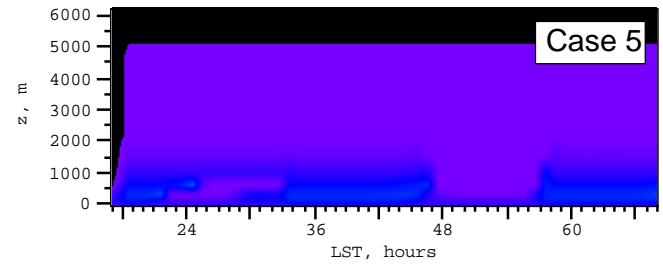
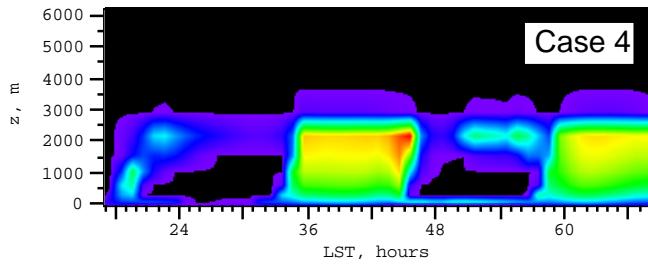
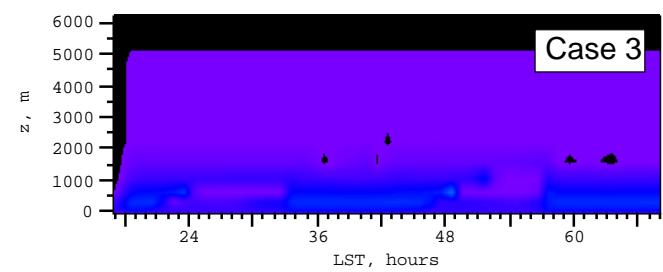
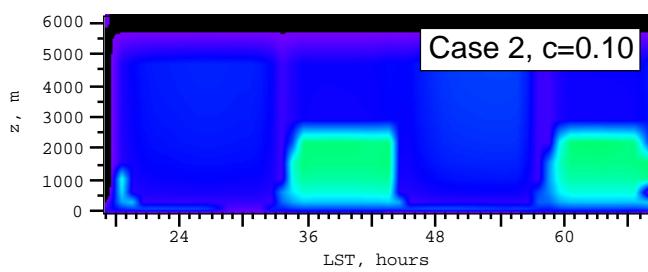
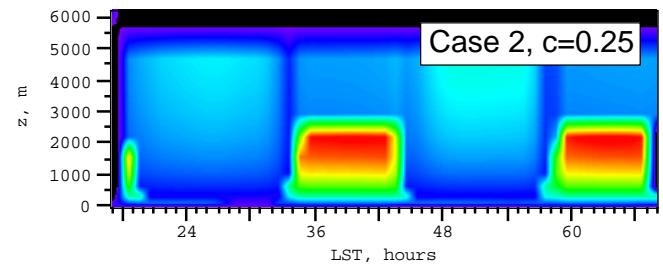
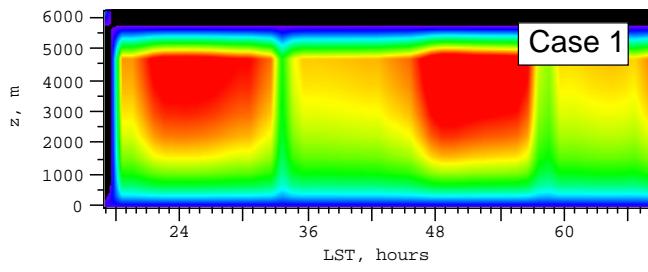
(Mellor & Yamada, 1974)

$$\ell_o = 0.00027 \cdot V_g / f$$

(Blackadar, 1962)

$$\ell_o = 100m$$

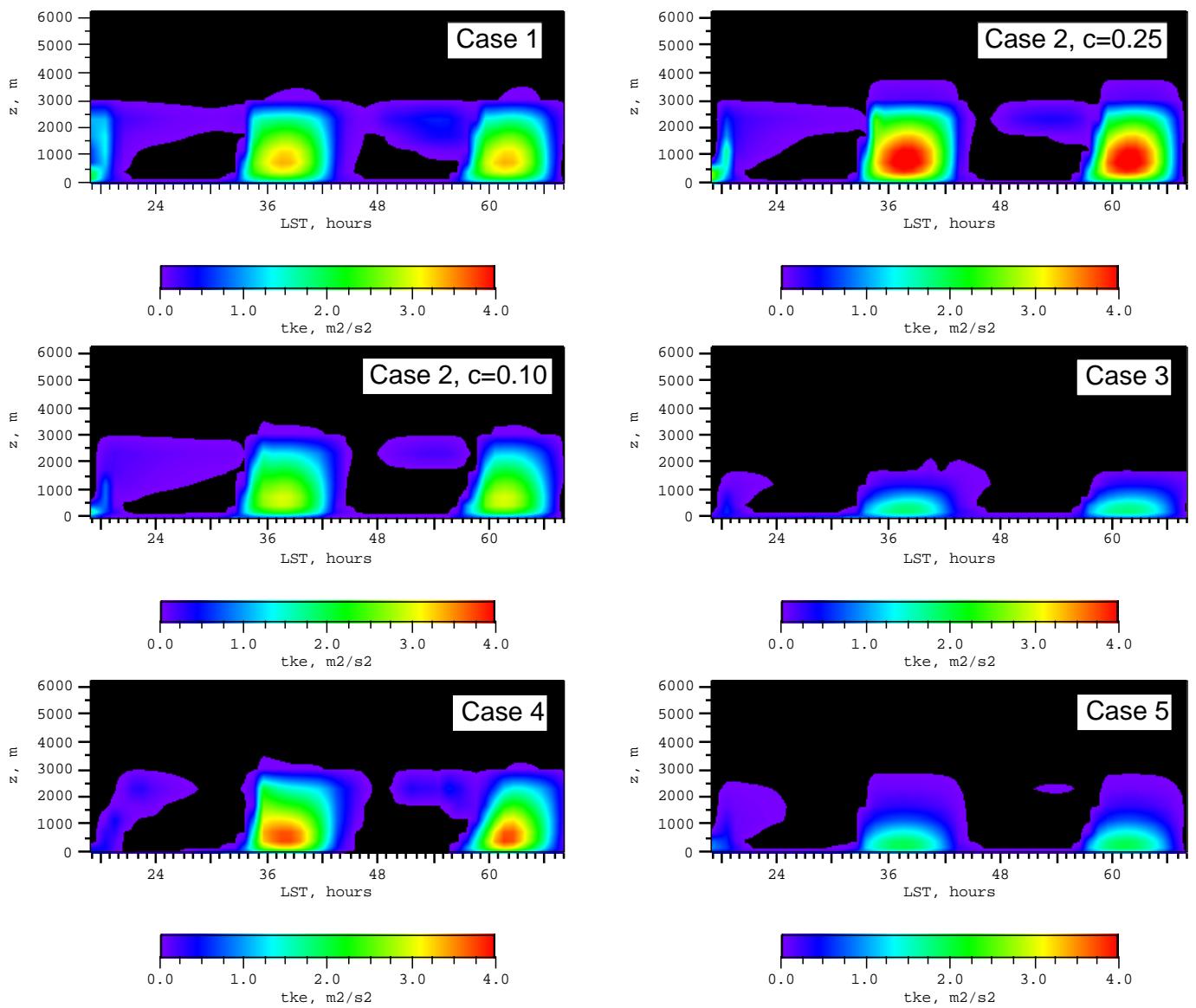
(Arritt, 1987)



Case 1 - neutral stability  $\zeta$   
 Case 2b - stability-dependent  $\zeta$ ,  $c=0.10$   
 Case 4 - stability-dependent dual-choice  $\zeta$

Case 2a - stability dependent  $\zeta$ ,  $c=0.25$   
 Case 3 - prognostic  $\zeta$  eqn.  
 Case 5 - prognostic dissipation and  
 diagnostic diffusivity  $\zeta$  scales

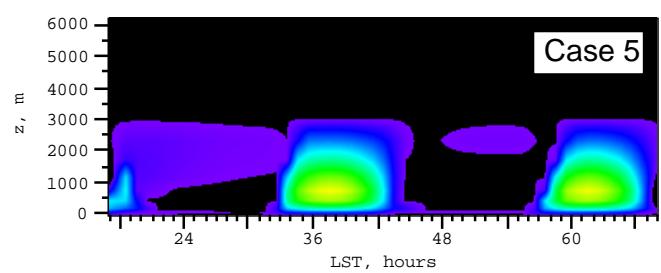
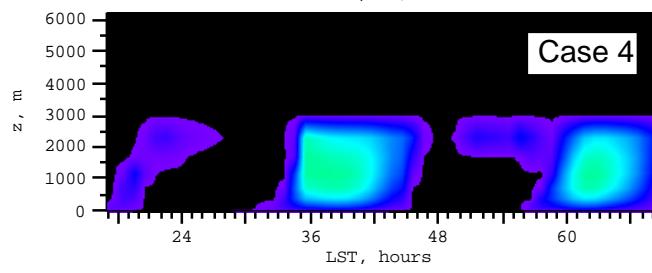
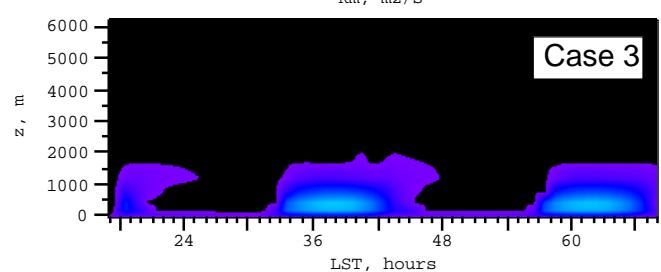
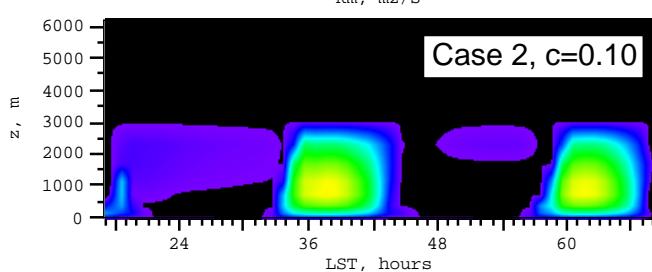
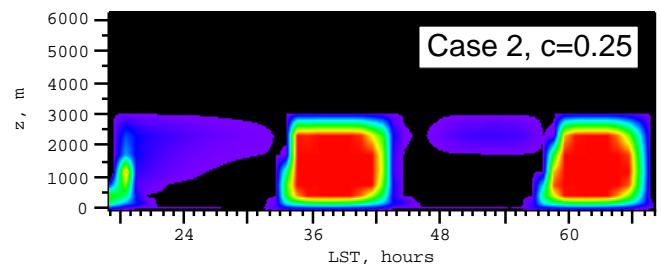
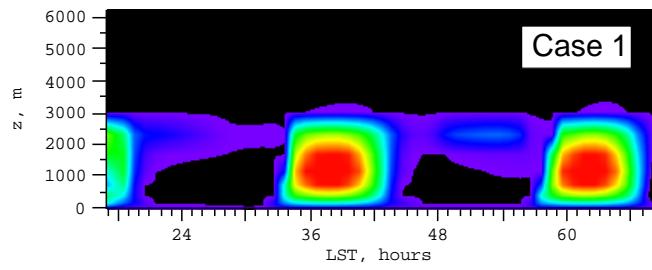
Comparison of model-computed length scale at the plain site for six variations of the length scale parameterization.



Case 1 - neutral stability  $\zeta$   
Case 2b - stability-dependent  $\zeta$ ,  $c=0.10$   
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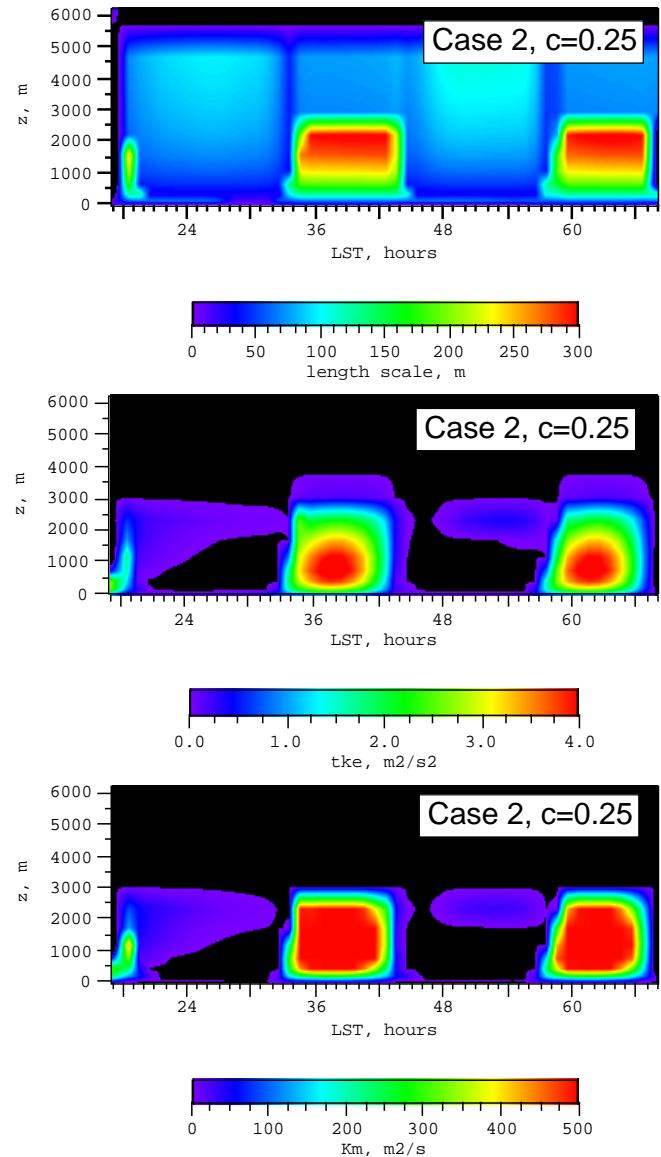
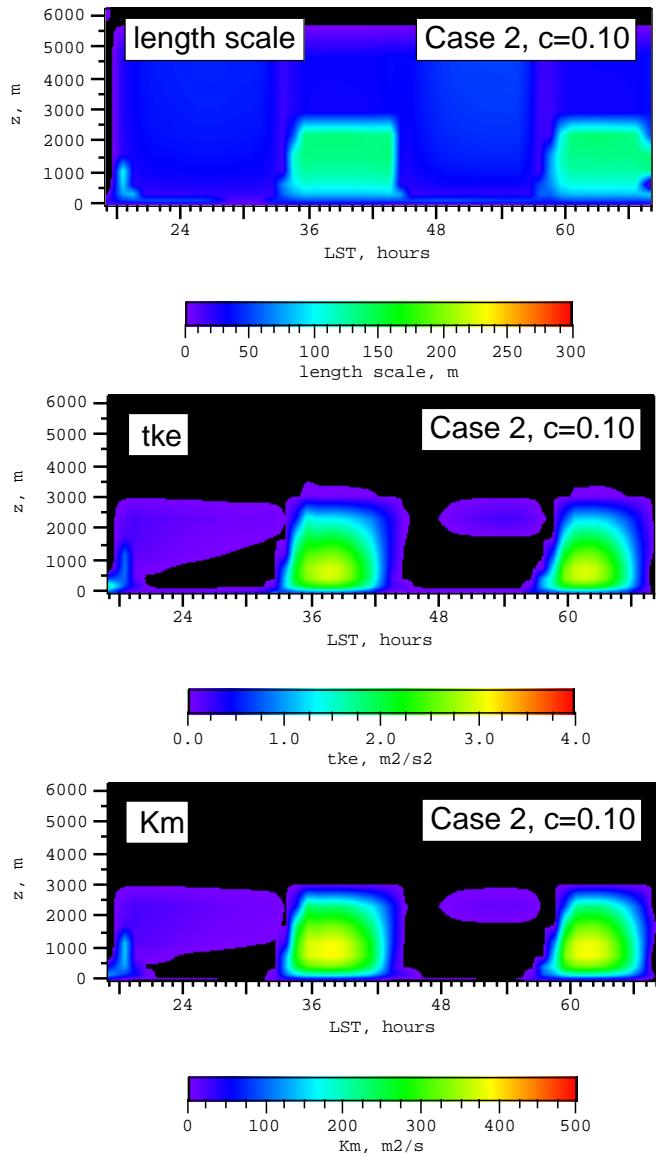
Comparison of model-computed turbulent kinetic energy at the plain site for six variations of the length scale parameterization.



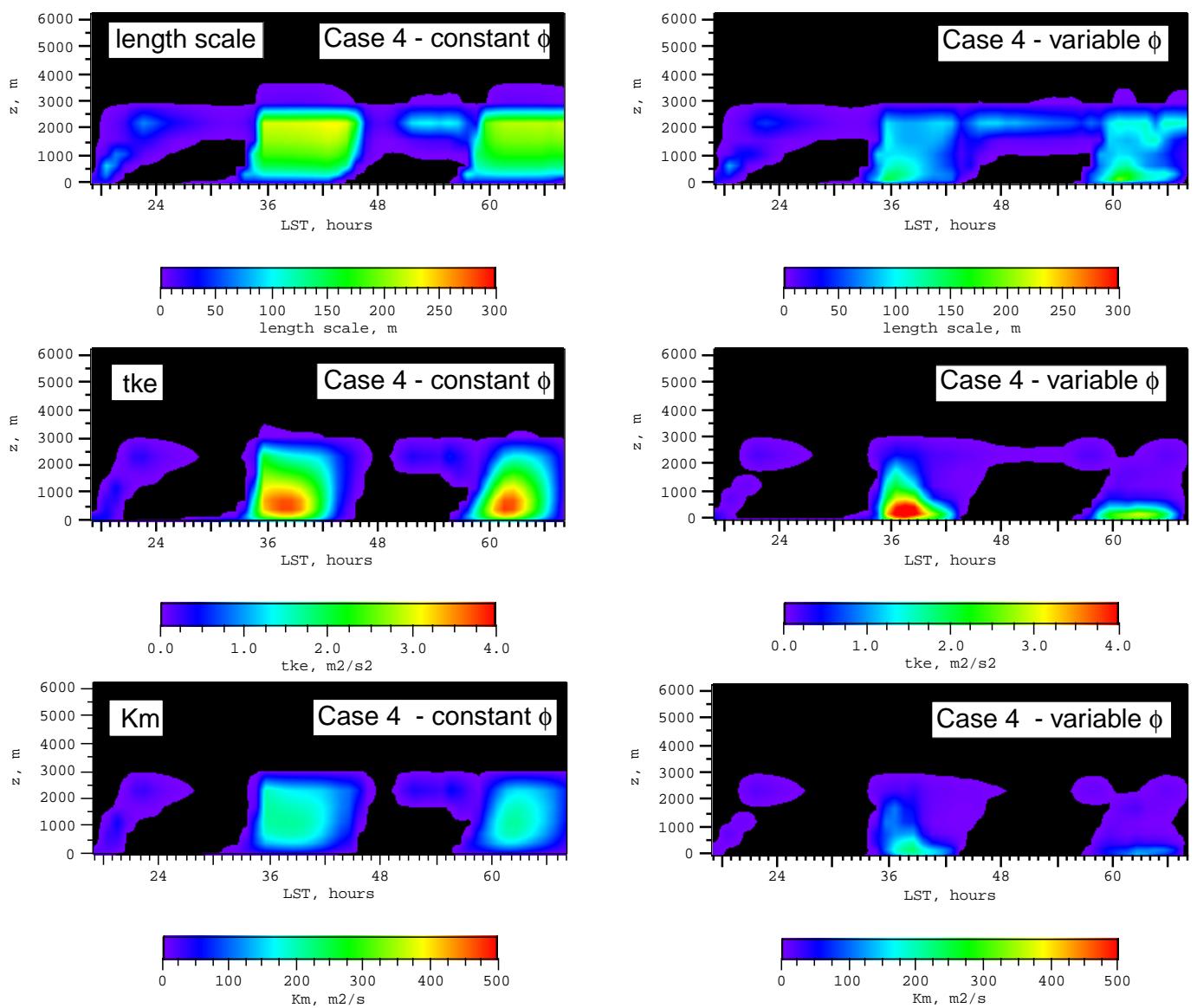
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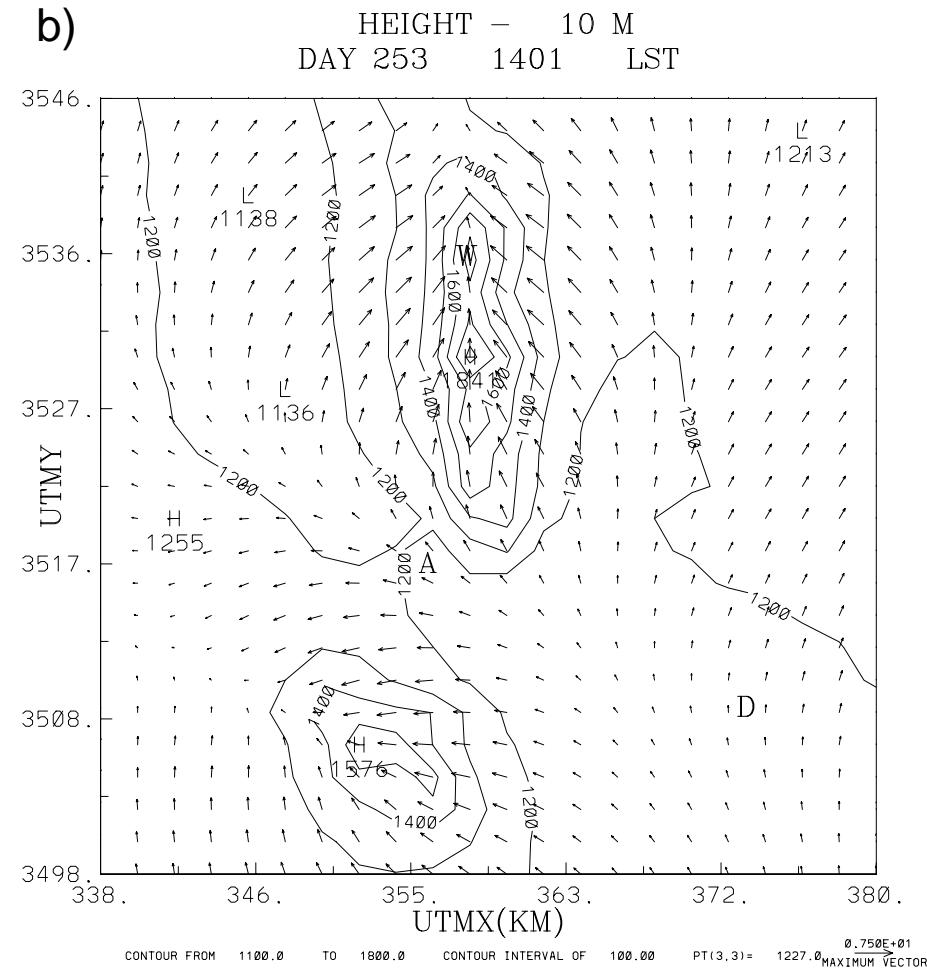
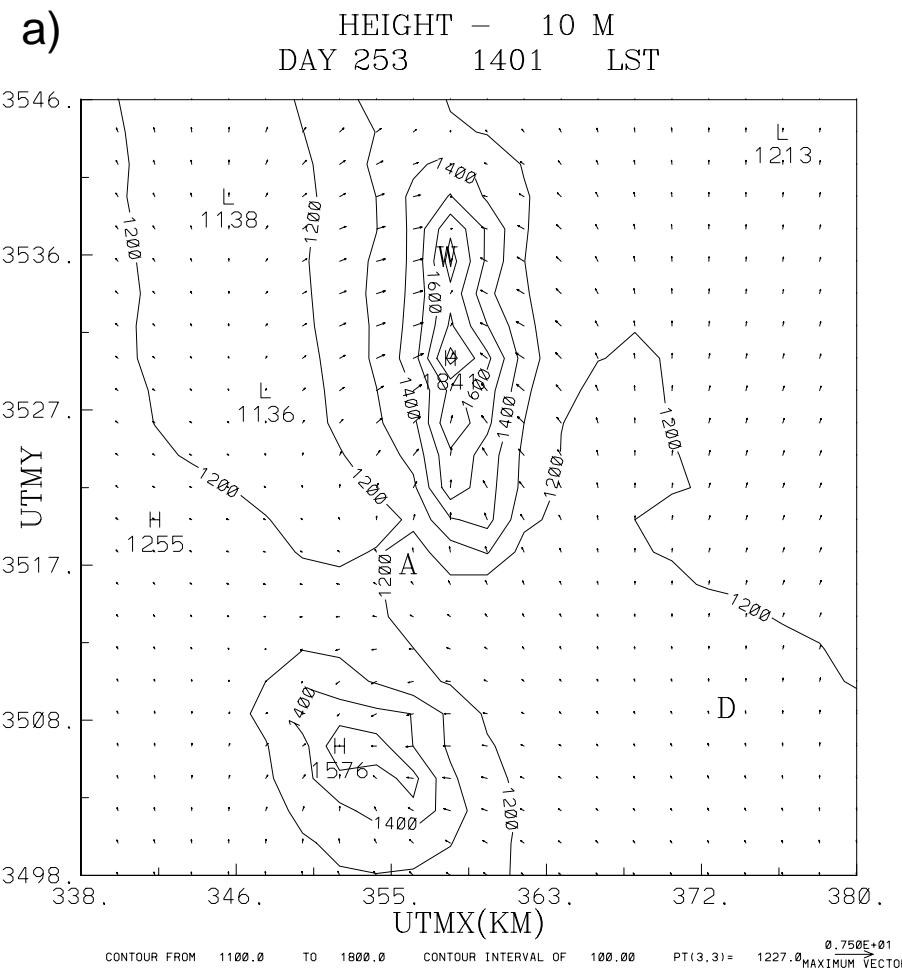
Comparison of model-computed vertical eddy diffusivity of momentum at the plain site for six variations of the length scale parameterization.



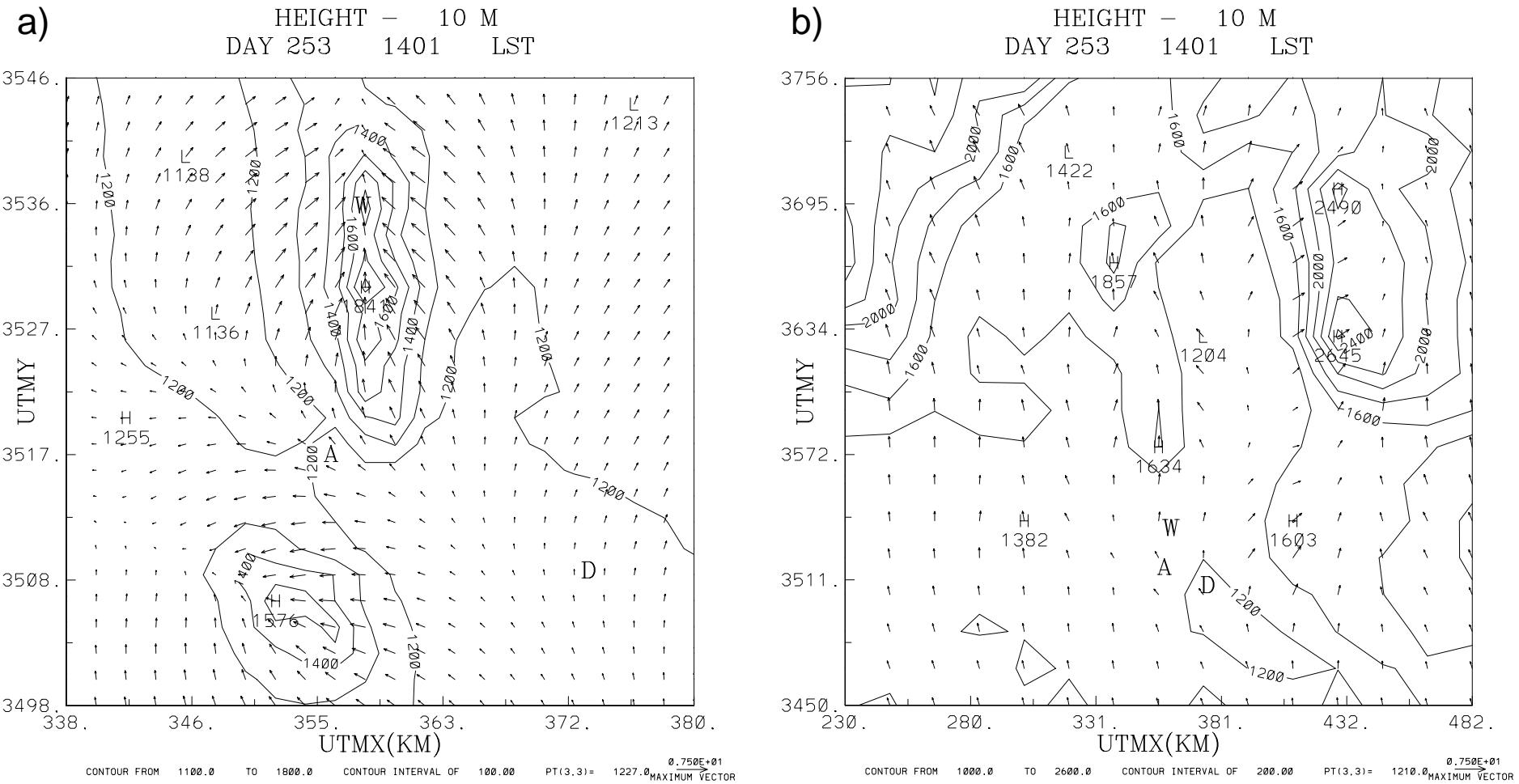
Comparison of length scale, tke, and  $K_m$  for the stability-dependent length scale (Case 2) with  $c = 0.1$  and  $0.25$ .



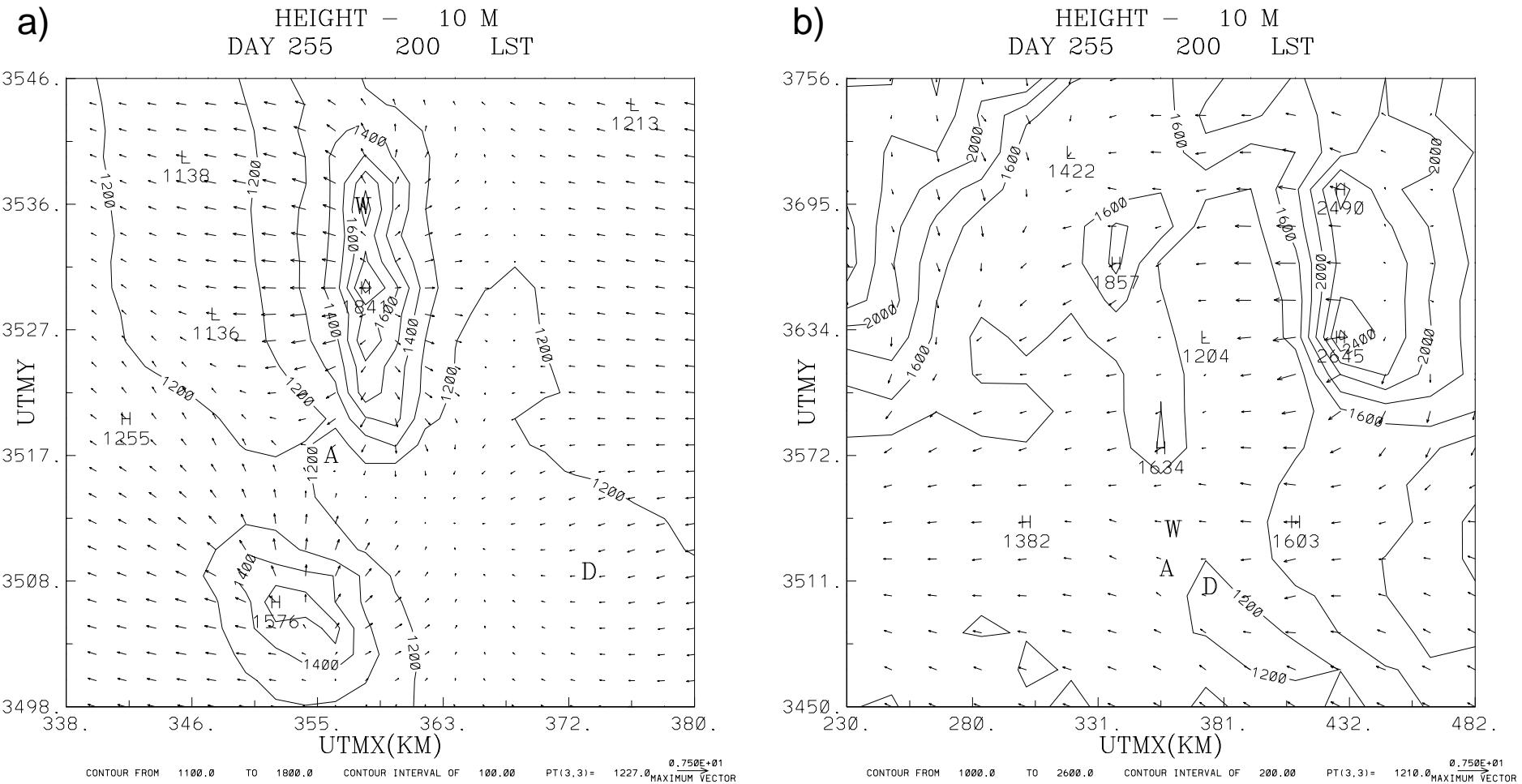
Comparison of length scale, tke, and  $K_m$  for the stability-dependent dual-choice length scale (Case 4) with constant and height-dependent  $\phi_m$ .



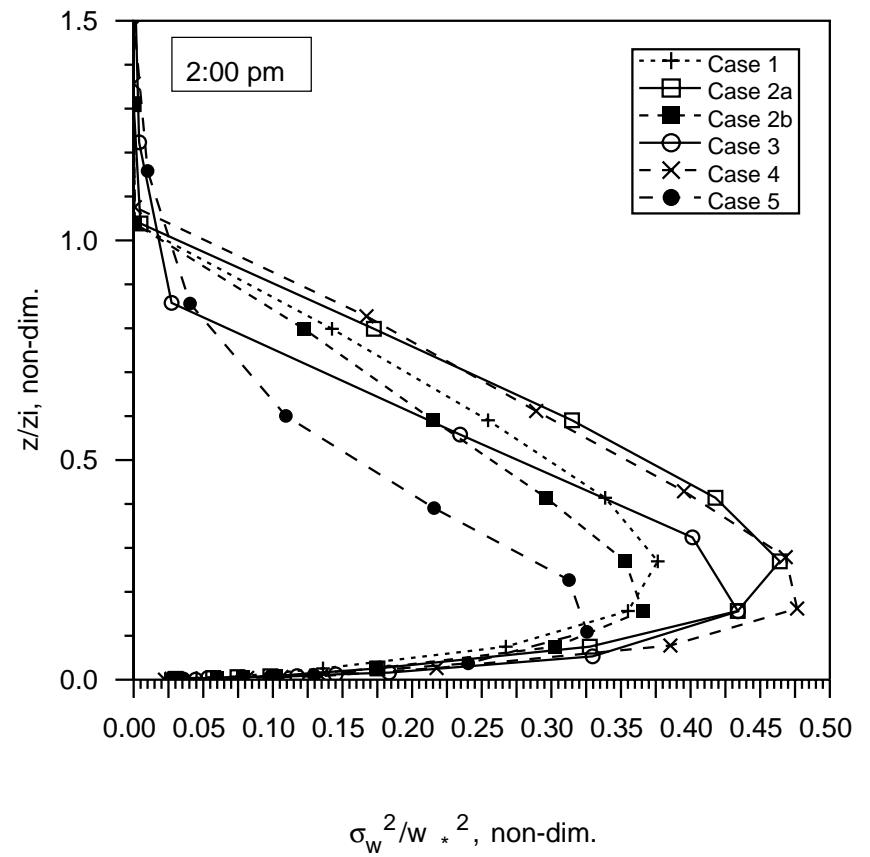
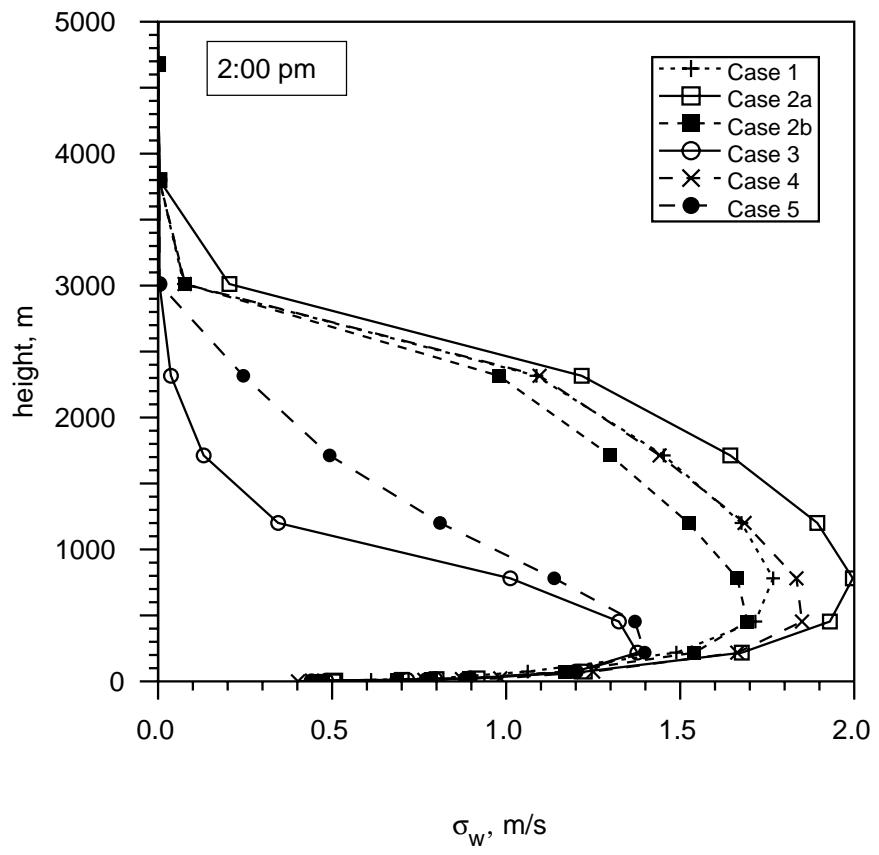
Comparison of 10m wind vector fields at 2:00 pm for a) Case 1 and b) Case 3. Lower winds were found for Cases 1, 2a, 2b, and 5. Higher winds were found for Cases 3 and 4.



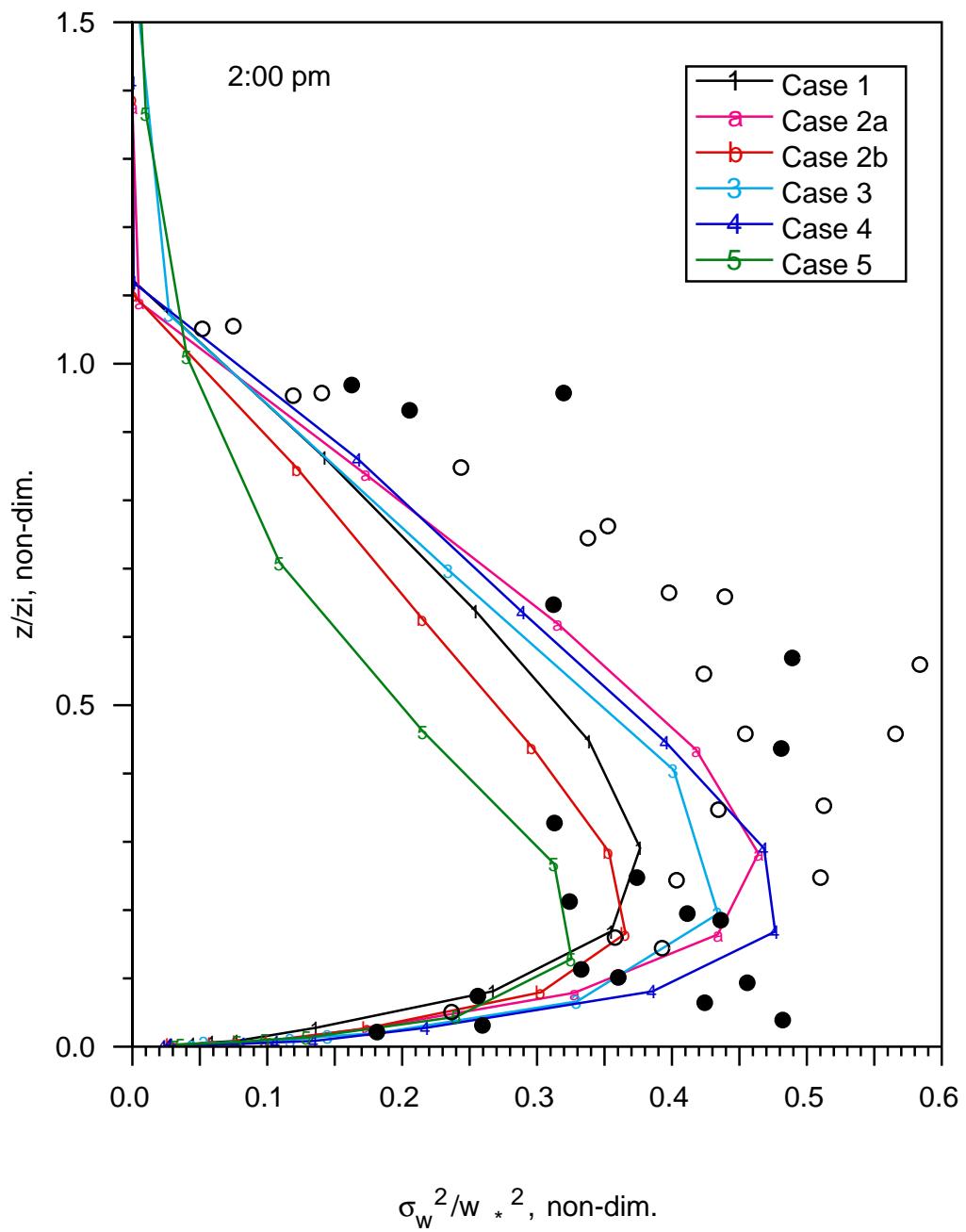
Ten meter wind vector fields at 2:00 pm on a) grid 3 and b) grid 1 for Case 3 (prognostic / eqn.). The northeasterly winds in the upper right hand corner of the inner grid result from long-range upslope flows seen on the outer grid. Is this realistic?



Ten meter wind vector fields at 2:00 am on a) grid 3 and b) grid 1 for Case 1 (diagnostic / eqn.). The westerly winds on the right side of the inner grid result from long-range down-slope flows originating on the outer grid. Is this realistic?



Comparison of model-computed afternoon vertical profiles of a)  $\sigma_w$  and b)  $\sigma_w^2/w_*^2$  at the valley site for the six different length scale parameterizations.



Comparison of measurements and model-computed vertical profiles of  $\sigma_w^2/w_*^2$ . Model results taken from 2:00 pm at the valley site for the six different length scale parameterizations. Measurements from Willis and Deardorff (1974): open symbols - laboratory experiments, closed symbols - aircraft measurements.